Fatal Avulsion of Choroidal or Perforating Arteries by Guidewires

Case Reports, *Ex Vivo* Experiments, Potential Mechanisms and Prevention

TIM E. DARSAUT[1], VINCENT COSTALAT[2], IGOR SALAZKIN[3], SARA JAMALI[3], FRANCE BERTHELET[4], GUYLAINE GEVRY[3], DANIEL ROY[5], JEAN RAYMOND[3,5]

[1] *Division of Neurosurgery, Department of Surgery, University of Alberta Hospital, Mackenzie Health Sciences Center; Edmonton, Alberta, Canada*
[2] *Service de Radiologie, CHU de Montpellier, Hôpital Gui de Chaulliac; Montpellier, France*
[3] *Laboratory of Interventional Neuroradiology, Centre Hospitalier de l'Université de Montréal, Notre-Dame Hospital Research Center; Montreal, Quebec, Canada*
[4] *Department of Anatomy and Pathology, Centre Hospitalier de l'Université de Montréal, Notre-Dame Hospital; Montreal, Quebec, Canada*
[5] *Department of Radiology, Centre Hospitalier de l'Université de Montréal, Notre-Dame Hospital; Montreal, Quebec, Canada*

Key words: aneurysm, avulsion, complication, endovascular treatment, guidewire

Summary

Innovations in endovascular tools have permitted an increasingly broad range of neurovascular lesions to be treated via minimally invasive methods. However, some device modifications may carry additional risks, not immediately apparent to operators.

A patient with a symptomatic, partially thrombosed basilar apex aneurysm was allocated balloon-assisted coiling. Attempts were made to place a microwire across the basilar apex through the posterior communicating artery. Overlapping courses of the posterior cerebral and posterior choroidal arteries on the roadmap images were not recognized and a flanged-tip microwire was inadvertently advanced deep into the choroidal artery. Following the wire with a microcatheter led to binding of arterial tissue within the microcatheter. Removing the wire led to an avulsion of the choroidal artery and a severe hemorrhagic complication which proved fatal. Tissue was identified on the tip of the guidewire. Pathology showed layers of vascular tissue within the laser-cut flanges of the distal wire tip.

A similar complication, also fatal, occurred during balloon angioplasty of a distal vertebral artery, when an exchange wire was accidently introduced into a perforator from a posterior cerebral artery.

Ex vivo catheterization of distal mesenteric arterial branches showed that the wall of small arteries can be entrapped by laser-cut, flanged, but not by smooth guidewire tips.

Microwires with a flanged instead of smooth distal tip, when placed into small caliber vessels, may cause hemorrhagic complications from avulsions.*

* The first case reported here was presented at the ABC-WIN meeting in Val d'Isère, January 2013.

Introduction

Devices for neurovascular interventions continuously evolve to provide interventionists with tools that allow them to reach and treat virtually any intracranial arterial lesion. Sophisticated techniques and advanced devices, however, are not without risk. Although most device modifications bring some benefit, some modifications may come with negative and sometimes potentially grave consequences. Here we describe a 51-year-old woman with an unruptured basilar aneurysm, where the inad-

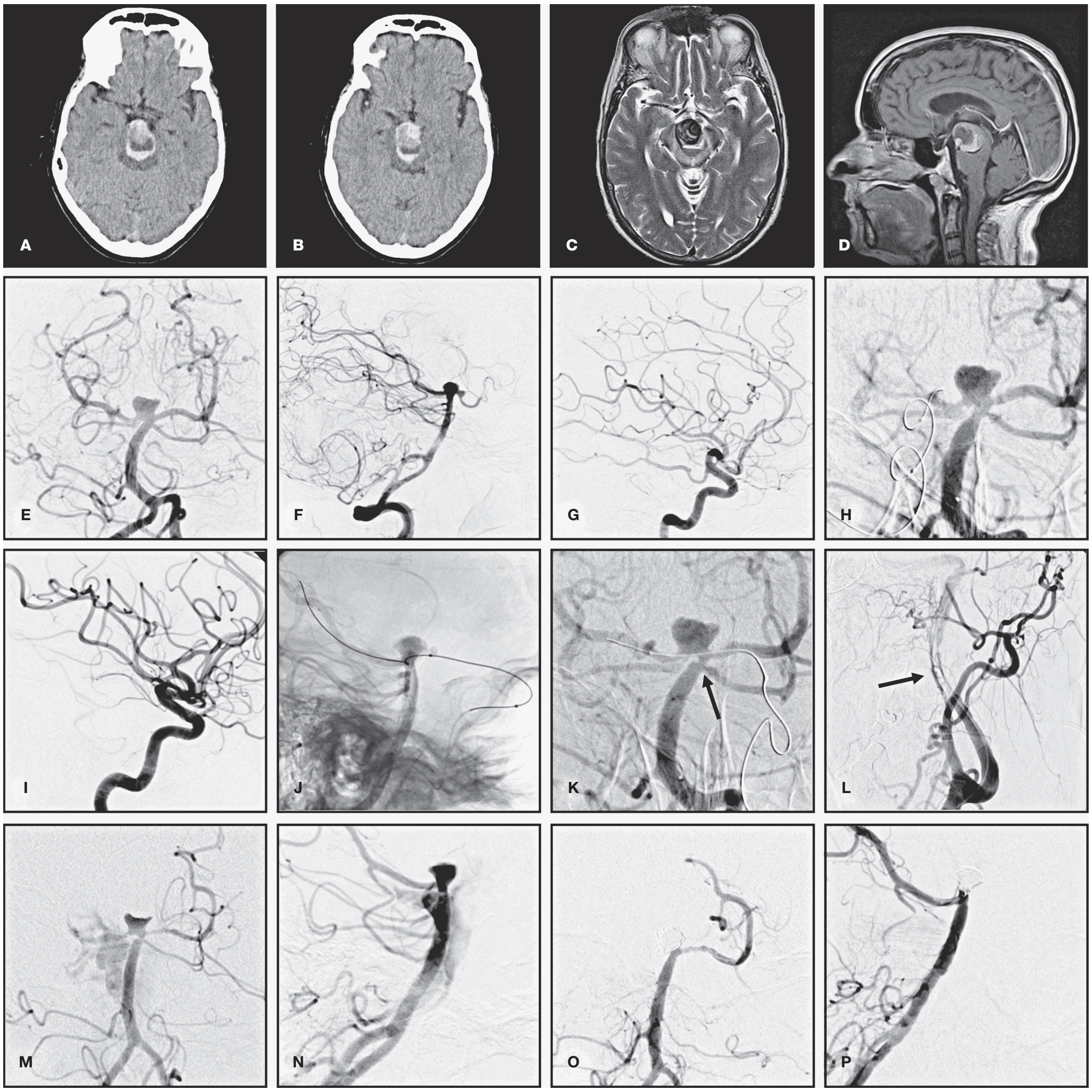


Figure 1 Case 1. CT (A,B) and MR (C,D) scans showed a giant, partially thrombosed basilar bifurcation aneurysm, with mural hematoma. E,F) Left vertebral angiography shows a small, broad-based patent residuum. G,H) Retrograde catheterization through the right posterior communicating artery was unsuccessful. I,J) Catheterization through the smaller left posterior communication artery allowed crossing of the basilar bifurcation but the wire was advanced far into the choroidal artery arising from the right posterior cerebral artery (J). K) The wire could no longer be retrieved without causing traction with deformation of the P1 basilar tip junction. When the guiding catheter was retrieved from the left internal carotid artery, where it had caused spasm and occlusion (L), the right posterior choroidal artery along with a segment of P1 were avulsed, with severe extravasation (M,N). O,P) The hemorrhage was controlled by coiling of the aneurysm and basilar apex.

vertent introduction of a micro guidewire into a posterior choroidal artery, in an attempt to coil the aneurysm using the retrograde balloon assisted technique (Figure 1), led to avulsion of the vessel with massive subarachnoid hemorrhage and death. A second case occurred during angioplasty of a distal vertebral stenosis, when an exchange wire was inadvertently introduced into a perforator. *Ex vivo* experiments were performed to attempt to explain how the wall of small vessels can be entrapped by guidewire tips.

Clinical Case 1

A 51-year-old woman presented with a progressive history of headaches, ataxia, memory loss and confabulation and a giant, partially thrombosed basilar bifurcation aneurysm embedded into the mesencephalon, with peri-aneurysmal edema. Investigations included plain CT head, CTA, MR, and catheter angiography (Figure 1A-D). Stent-assisted coil embolization of the residual lumen of the aneurysm was contemplated and the patient consented to participation in the STAT trial, a randomized trial comparing stent-assisted coiling with non-stent assisted coiling [1]. The patient was allocated to non-stent-assisted coiling. In this particular case, retrograde balloon-assisted coiling, using one or the other posterior communicating artery, was elected to attempt dense packing of the wide-necked (4.5 mm) but shallow (4 mm) patent residuum of the partially thrombosed aneurysm (Figure 1E,F). After general anesthesia and bifemoral punctures, a 5000 IU heparin IV bolus was administered and the ACT kept above 300 seconds throughout the procedure. The right femoral artery was used to place a 6F guiding catheter into the right vertebral artery. One SL-10 microcatheter (Stryker, Kalamazoo, MI, USA) and one balloon catheter (4×20 mm Scepter balloon; Microvention, Tustin, CA, USA) were then positioned in the basilar and vertebral arteries. The left femoral artery was used to reach the right internal carotid artery with a 5F guiding catheter. Attempts were made to reach the basilar apex through the right posterior communicating artery using a HyperGlide balloon (Covidien, Irvine, CA, USA) but the X-Pedion guidewire (eV3, Plymouth, MN, USA) could not be torqued into the P1 segment of the right posterior cerebral artery without entering a 1mm aneurysm at the P1-P2 junction (Figure 1G,H). The right-sided approach was abandoned for another attempt to place the balloon through the smaller left posterior communicating artery (Figure 1I,J). Planning for an eventual exchange over a long guidewire, an SL-10 microcatheter was used to reach the left posterior communicating artery but the guidewire (Terumo Goldwire 12; Burlington, Ont. Canada) would always go into the incorrect (left) P2 segment of the posterior cerebral artery. After multiple attempts, the wire was changed for a Synchro[2] guidewire (Stryker, Kalamazoo, MI, USA). This wire could make the turn into the left P1 segment, and successfully reached the aneurysm; it was retrieved and positioned into the right superior cerebellar artery, retrieved again to finally reach the right posterior cerebral artery, across the neck of the aneurysm. The wire was then advanced under road map control far into what was thought to be the distal right posterior cerebral artery (Figure 1J). A seemingly acceptable position was achieved and the microcatheter was advanced over the wire. The microcatheter encountered some resistance as it was advanced, with arrest of progression at the level of P1 and retrograde movement of the guidewire tip. Reviewing the previous location of the guidewire, it was recognized that the wire had not been following the map of the distal cerebral artery (Figure 1J). At that moment, control angiography did not reveal any leak of contrast, but it was now impossible to retrieve the wire inside the catheter, and traction on the catheter would lead to deformation of the P1 segment of the right posterior cerebral artery (Figure 1K). Intra-arterial injection of milrinone and progressive gentle traction of the microcatheter were then attempted over 15 minutes. Each time the microcatheter would be retrieved in 1 cm increments and the microcatheter locked by the hemostatic valve. Control angiograms were performed until a left carotid occlusion was noticed. This was caused by traction of the microcatheter and advancement of the guiding catheter over the microcatheter into a spastic segment of the cervical carotid artery. The guiding catheter was retrieved to re-establish left carotid flow (Figure 1L), forgetting this would lead to forceful traction on the microcatheter fixed by the hemostatic valve. Control angiography from the right vertebral artery showed contrast extravasation from the P1 segment of the right posterior cerebral artery (Figure 1M,N). Heparinization was reversed with protamine and the basilar artery was temporarily occluded with the Scepter balloon (already in place). The patient was found to have dilated pupils, and an external ventricular drain was urgently placed to relieve CSF under pressure. After ventricular drainage, the extravasation was controlled by occluding the basilar apex aneurysm and right P1 segment with platinum coils in an effort to staunch the hemorrhage (Figure 1O,P). Some extravasation persisted through the right posterior communicating artery, but abated as catheterization of the right P1 was attempted from the right carotid artery. Catheters were retrieved. A post-procedural CT scan demonstrated a large volume subarachnoid he-

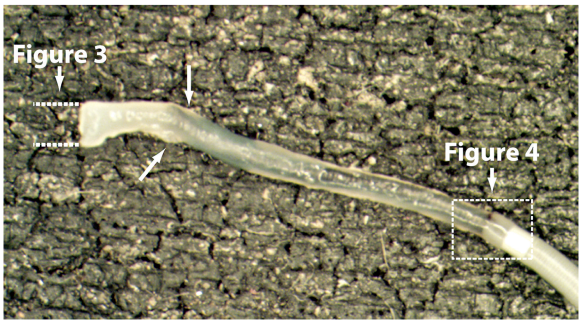


Figure 2 The microcatheter guidewire combination was photographed, after the tissues beyond the wire tip has been cut and sent for pathological examination (Figures 3, 4). Note the junction between the choroidal artery and its everted origin, along with a segment of P1, containing distal microvascular structures (shown in Figure 3, explained in Figure 6).

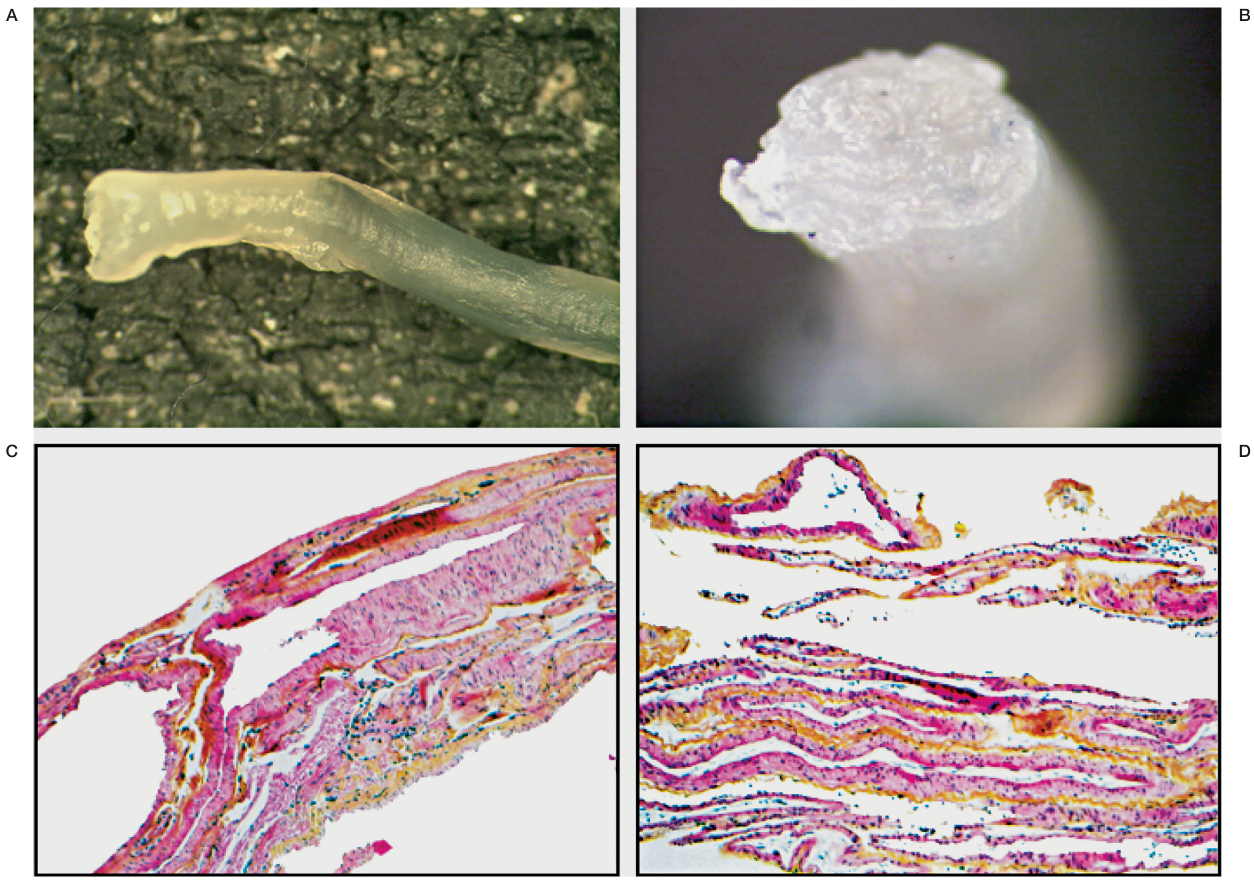
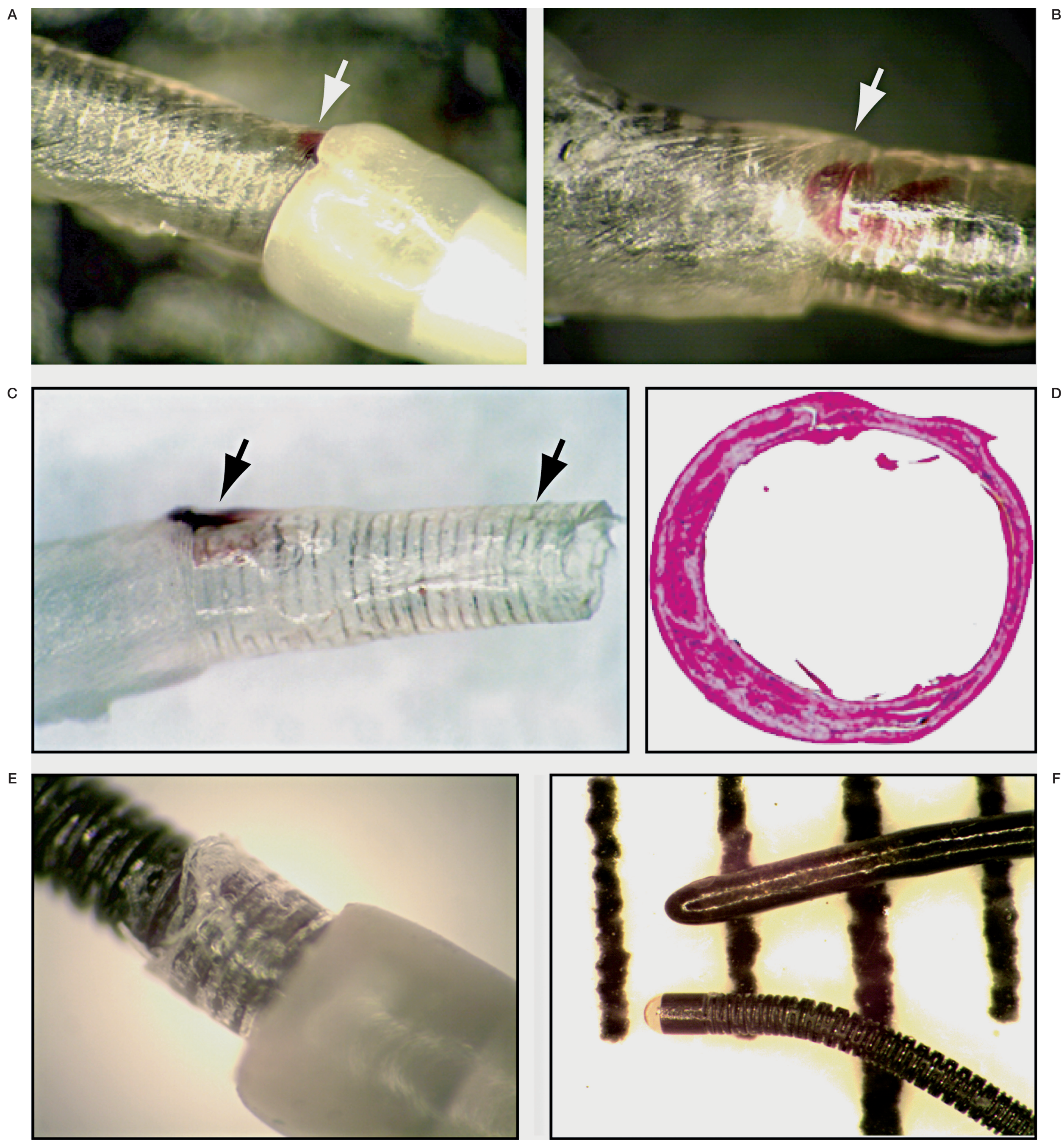


Figure 3 The cross-section of the material found on the wire showed an arterial lumen (A,B) filled with microvascular structures and nerves (C,D; Hematoxylin and eosin staining × 100).

morrhage. Two days later the patient underwent an MRI of the brain which showed bi-thalamic damage, and care was withdrawn.

At the end of the procedure, examination of the tip of the catheter revealed some solid material extending beyond the tip of the guidewire protruding beyond the microcatheter. The solid material was cut off beyond the tip of the wire, put into formalin and sent for pathological examination. The distal segment of the microcatheter along with the guidewire tip were cut with scissors 3 cm proximal to the extremity, placed in formalin and examined with a stereomicroscope (Figure 2). The cylindrical piece of tissue extending beyond the guidewire tip was found to contain multiple arterioles, as well as veins and nerves (Figure 3A-D). Examination of the catheter tip revealed a small vessel wall

 Interventional Neuroradiology 20: 251-260, 2014 - doi: 10.15274/INR-2014-10023



hematoma where the artery had been squeezed inside the microcatheter (Figure 4A,D). Further careful microscopic dissection revealed that the microcatheter contained the guidewire, itself inside at least three contused and compressed vessel wall layers (Figure 4D). The imprinting of the distal wire screw-like design could be clearly seen on the wall of the vessel taken out of the microcatheter (Figure 4C).

↑
Figure 4 The microcatheter tip showed entrapment of the vessel wall, a small parietal hematoma (arrows in A-C) and dissection of the tip showed how the vessel wall was indented by the tip of the wire and intussuscepted inside the microcatheter (C,D). E) Pushing the wire showed more vascular wall entrapment inside slits of microwire. F) The tips of the smooth standard and laser-cut microwires are shown.

Pushing the wire through the catheter extruded more vessel wall pieces trapped inside the slits of the wire (Figure 4E). The laser-cut slits that are part of the design of the distal tip of the guidewire used in this case report are shown and compared to the smooth tip of our standard wire in Figure 4F.

Clinical Case 2

A 74-year-old man presented with recurring symptoms from a distal vertebral artery stenosis despite I.V. heparin and antiplatelet therapy for ten days. A triaxial system composed of a Destination 7F (Terumo Europe, Leuven, Belgium), a DAC (Concentric medical, Mountain View, CA, USA) 0.44, 115 cm, and a Headway microcatheter (Microvention, Tustin, CA, USA) were used to catheterize the left posterior cerebral artery with a 300 cm Transend soft tip exchange wire (Stryker, Kalamazoo, MI, USA). During this maneuver, the distal tip of the wire entered a perforating artery of the left P1 segment. It was impossible to retrieve the microguide wire despite many attempts over 15 minutes. No bleeding was observed on the control angiogram at this time. Angioplasty was performed over the wire in order to not delay brain reperfusion. Intra-arterial nimodipine was administered (4 mg) without any results. The angioplasty balloon was retrieved, and the DAC as well. A second hemostatic valve was placed at entrance of the 7F destination in order to independently place a remodeling balloon in front of the perforating artery where the first guidewire was still locked into position. With balloon inflation and additional maneuvers the guidewire was finally retrieved. Immediate angiographic control showed extravasation in the posterior fossa. The balloon was inflated immediately for five minutes, but just after deflation, bleeding restarted. Thirty minutes were necessary to stop the bleeding (6×5 minutes). The final angiogram showed no pseudo-aneurysm. The patient was not extubated and CT at 24 hours showed extensive brainstem ischemic lesions. The patient died on day 4.

After the intervention the endovascular material was inspected and showed a vascular structure stretched and attached to the distal, screw-like segment of the guidewire tip. It was not possible to separate the vessel from the guidewire, but the material was not sent to pathology.

***Ex vivo* experiments**

The mesentery and adjacent arterial segments of small intestines were resected at the time of autopsy of two animals used for abdominal aortic aneurysm research (25-27 kg mongrel dogs) and immersed in saline at room temperature. Experiments were performed in two sessions completed within three hours of autopsy. A co-axial system was used to catheterize the mesenteric artery; a SL-10 microcatheter (Stryker) and various guidewires (Terumo Goldwire 12; Transend exchange wire or Synchro2 guidewire) were navigated as far as possible into distal branches (n =6 for each wire). On five of six occasions, the arterial wall could be captured by the Synchro wire and pulled towards the catheter tip, with retraction of surrounding tissues (Figure 5), while this phenomenon could not be reproduced with the Terumo or Transend wires, despite vigorous attempts. Intussusception of the distal vessel into the microcatheter, and avulsion or 'biopsy' of the vessel wall, however, was not possible despite multiple attempts.

Discussion

Hemorrhagic complications of endovascular treatment of aneurysms occur more frequently with ruptured than unruptured aneurysms [2], and more readily in small than large ruptured aneurysms [3]. The clinical consequences of these complications vary from one report to another [2,4,5]. Most complications are due to aneurysm perforations or ruptures by microcatheters, coils or microwires [6], although guidewire perforation of normal vessels can also occur, especially when exchange maneuvers are performed for stent-assisted coiling [7], or for angioplasty. While wire perforations may be less morbid than aneurysm ruptures [2], clinical consequences may still be grave when patients have been premedicated with a double antiplatelet regimen [7]. A standard checklist of procedural steps designed to minimize the clinical impact of hemorrhagic complications has been proposed [8]. With the use of balloon assistance, hemostasis can usually be secured [3,9,10] while the aneurysm or perforation is sealed, typically with coils or less frequently with liquid embolic agents [11].

In the present cases, the hemorrhage was severe because the vessels were not punctured

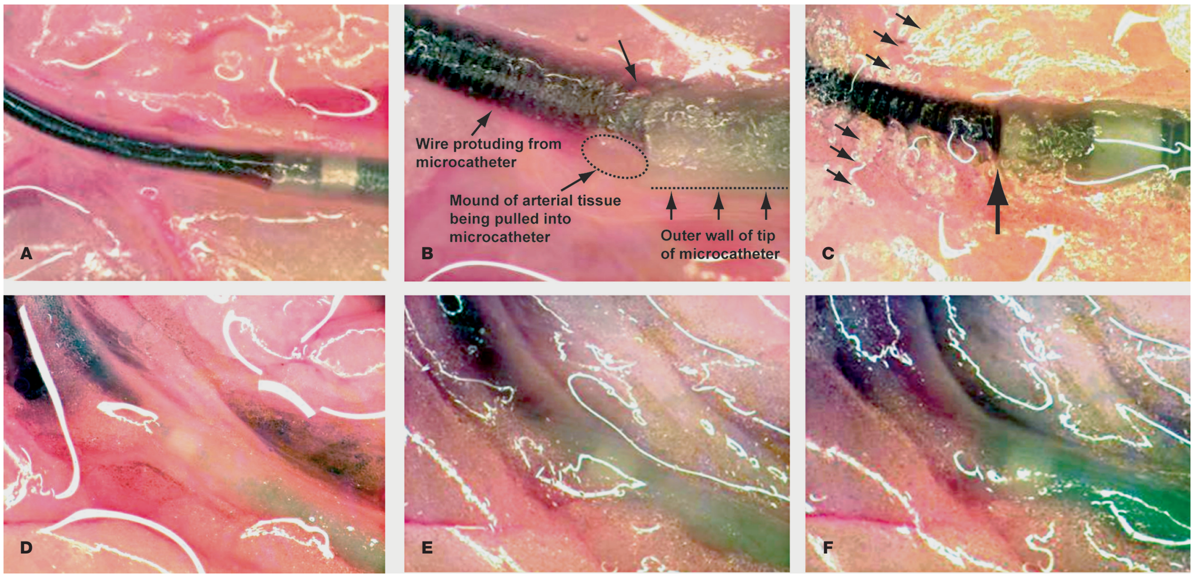


Figure 5 *Ex vivo* experiments. Laser-cut wire tips (A-C) can entrap the wall of small mesenteric arterioles (arrows in B), with traction on surrounding tissues when the wire is pulled inside the microcatheter (arrows in C), but the smooth wire tips (D-F) cannot.

but avulsed. Our interpretation of the first case is as follows. Distal penetration of a very small vessel was possible because the choroidal artery makes a long gentle non-bifurcated turning segment around the brainstem that can mimic or be superimposed on the trajectory of the posterior cerebral artery. When the microcatheter was advanced over the wire, it could only follow until it was too large to penetrate the vessel further. Additional pushing led to wire retraction, but the distal wire microstructure had already trapped the wall of the distended and stretched vessel wall inside its slits. Traction could only bring the proximal segment of the choroidal artery first inside the microcatheter, with further entrapment of the vessel wall, now intussuscepted and squeezed between the screw-like wire tip and microcatheter, then with further traction, inside P1. Forceful traction of the guiding catheter in the cervical carotid artery later on led to avulsion of the choroidal artery, its distal branches along with a network of microscopic veins and nerves, and a segment of P1, resulting in a large vascular tear.

The three wires we studied had different tips. The smooth Terumo wire tip is compared to the 'harpoon-like' slits of the Synchro in Figure 4F. Intermediate in appearance is the screw-like tip of the Transend 300. The tip configuration for both Transend 300 ES (Extra Support) and Transend 300 Floppy differs from the standard length Transend wires. It is made of a 3 cm platinum coil, not covered by the polyurethane jacket, with spaces between the turns of the primary wire that could conceivably entrap tissues, although this phenomenon could not be demonstrated in our *ex vivo* experiments. Thus the type of injury and the hemorrhagic complication that occurred in case 2, not as well documented as in case 1, may not be related to the guide wire tip morphology.

Many different mechanisms can be postulated to explain avulsion of small vessels, but in the absence of pathological confirmation, most remain speculative. While dissection of the vessel, perhaps compounded by vasospasm, could conceivably lead to avulsion of small intracranial vessels, the pathological specimen retrieved in our first case, with the many layers of vessel wall symmetrically and concentrically found around the wire, was not suggestive of a dissection. Unfortunately we did not have pathological confirmation in the second case, and a perforation, initially sealed by the guidewire, or a dissection, cannot be excluded, although the presence of tissues extending beyond the wire tip at the end of the procedure, a finding we had never encountered in other cases of perforation or dissection, made us

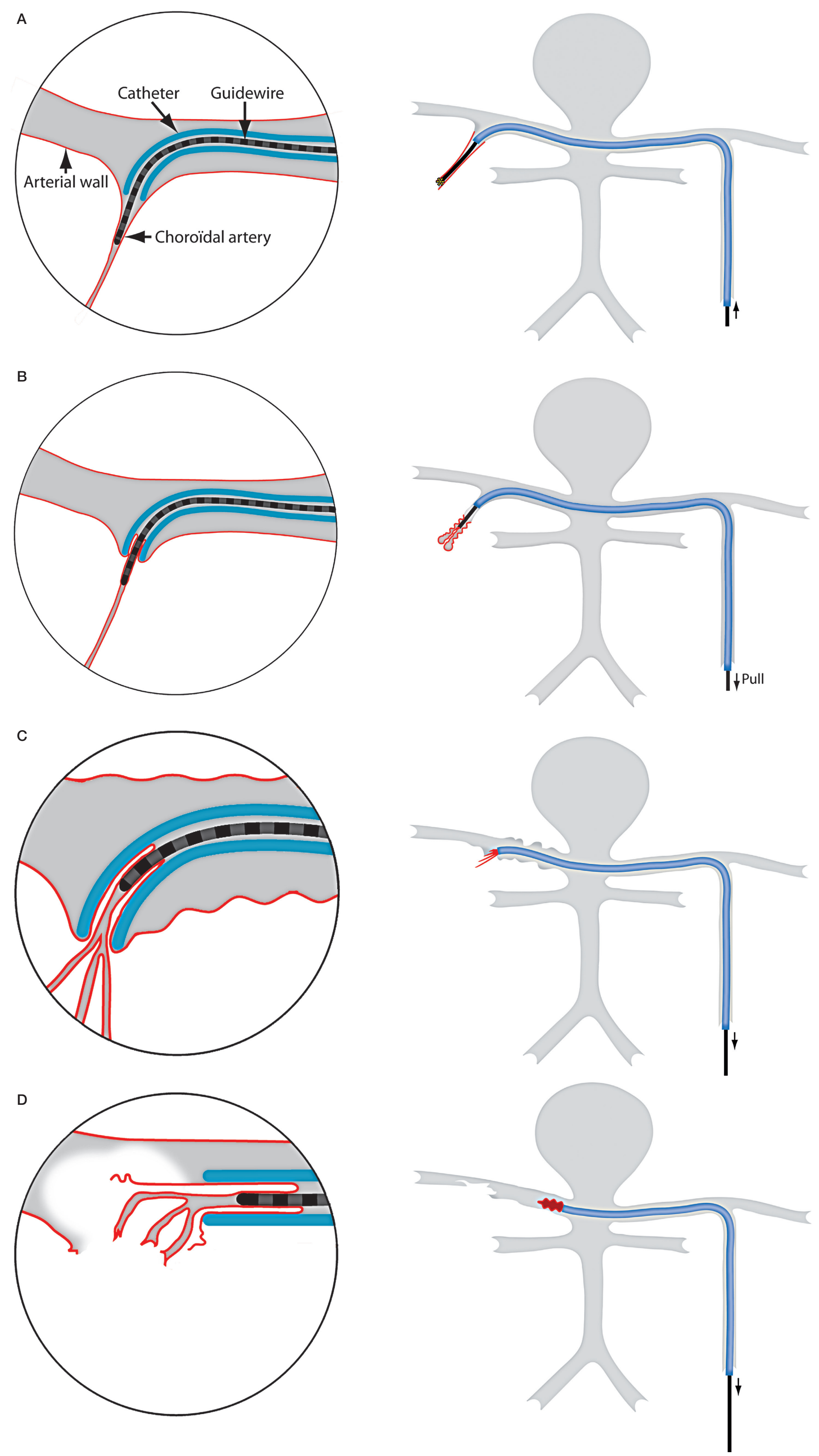


Figure 6 Artistic representation of the mechanism of avulsion in Case 1. A) Step one: the microwire inadvertently entered the choroidal vessel, where it trapped the vessel wall (see insert). B) Step two: with traction, the wire pulled the proximal choroidal artery and intussuscepted the vessel inside the microcatheter, which now contains 2 vessel walls, and the wire-catheter apparatus is stuck. C) Step three: with further traction, the proximal choroidal artery is pulled inside the P1 segment of the posterior cerebral artery. D) Step 4: With tearing of a segment of P1 and origin of posterior choroidal artery, the distal choroidal branches (along with arterioles and venules) are torn and contained within a segment of reversed P1.

postulate that the mechanism was similar to case 1.

We have not found a publication reporting a similar complication. When this case was presented at the WIN (Working Group in Interventional Neuroradiology) meeting in Val d'Isère in January 2013, some members of the audience mentioned that the complication was probably caused by vasospasm. We believe vasospasm cannot fully explain this very rare problem. The careful dissection and microscopic examination of the pathological material found at the extremity of the catheter-guidewire combination are evidence that the configuration of the wire tip can act as a harpoon in very small vessels, as was demonstrated by the *ex vivo* experiments we performed. Vasospasm may play a role, and in our *ex vivo* model the lack of vasospasm may perhaps explain why avulsion of the vessels was not possible. We believe such complications could be avoided by choosing smooth-tipped guidewires whenever possible. Guidewires which feature a screw-like distal tip, like the Synchro, fabricated by laser-cutting of a nitinol hypotube, and designed to improve torque control, may have facilitated penetration of the small choroidal artery, the harpooning of the vessel wall, which, combined with retrieval of the wire inside the catheter, led to intussusception inside the posterior cerebral artery, trapping the choroidal arterial wall between the wire and microcatheter, and with forceful traction, to arterial avulsion of the origin of the choroidal artery and part of the wall of the posterior cerebral artery (Figure 6).

A wire which has perforated the vasculature is typically free to move forward or backward (but it should not be retrieved [8]). What is distinctive in the present situation is that the wires were stuck. Once a microwire with a flanged tip is found to be irretrievable with gentle traction, it should probably be left in situ to prevent arterial avulsion and severe hemorrhagic complications. Leaving wires in situ has previously been reported [12].

Conclusion

Modifications to the tips of some endovascular wires may potentially increase the risk of avulsion of small vessels when these are inadvertently catheterized. Clinicians should be aware of which wires feature this microscopic character when they are attempting to catheterize blood vessels in the vicinity of perforators. When wires are irremediably entrapped, they should probably be left *in situ*.

References

1 Darsaut TE, Raymond J. The design of the STenting in Aneurysm Treatments (STAT) trial. J Neurointerv Surg. 2012; 4 (3): 178-181. doi: 10.1136/neurintsurg-2011-010065.
2 Cloft HJ, Kallmes DF. Cerebral aneurysm perforations complicating therapy with Guglielmi detachable coils: a meta-analysis. Am J Neuroradiol. 2002; 23 (10): 1706-1709.
3 Nguyen TN, Raymond J, Guilbert F, et al. Association of endovascular therapy of very small ruptured aneurysms with higher rates of procedure-related rupture. J Neurosurg. 2008; 108 (6): 1088-1092. doi: 10.3171/JNS/2008/108/6/1088.
4 Brisman JL, Niimi Y, Song JK, et al. Aneurysmal rupture during coiling: low incidence and good outcomes at a single large volume center. Neurosurgery. 2005; 57 (6): 1103-1109. doi: 10.1227/01.NEU.0000185631.20246.1A.
5 Kwon BJ, Chang HW, Youn SW, et al. Intracranial aneurysm perforation during endosaccular coiling: impact on clinical outcome, initial occlusion, and recanalization rates. Neurosurgery. 2008; 63 (4): 676-672; discussion 682-683. doi: 10.1227/01.NEU.0000325500.73330.C2.
6 Doerfler A, Wanke I, Egelhof T, et al. Aneurysmal rupture during embolization with Guglielmi detachable coils: causes, management, and outcome. Am J Neuroradiol. 2001; 22 (10): 1825-1832.
7 Piotin M, Blanc R, Spelle L, et al. Stent-assisted coiling of intracranial aneurysms: clinical and angiographic results in 216 consecutive aneurysms. Stroke. 2010; 41 (1): 110-115. doi: 10.1161/STROKEAHA.109.558114.
8 Taussky P, Lanzino G, Cloft H, et al. A checklist in the event of aneurysm perforation during coiling. Am J Neuroradiol. 2010; 31 (7): E59. doi: 10.3174/ajnr.A2140.
9 Layton KF, Cloft HJ, Kallmes DF. Cerebral aneurysm perforations during treatment with detachable coils. Use of remodelling balloon inflation to achieve hemostasis. Interv Neuroradiol. 2006; 12 (1): 31-35.
10 Santillan A, Gobin YP, Greenberg ED, et al. Intraprocedural aneurysmal rupture during coil embolization of brain aneurysms: role of balloon-assisted coiling. Am J Neuroradiol. 2012; 33 (10): 2017-2021. doi: 10.3174/ajnr.A3061.
11 Kostov D, Kanaan H, Lin R, et al. Repair of intracranial vessel perforation with Onyx-18 using an exovascular retreating catheter technique. J Neurointerv Surg. 2012; 4 (2): 121-124. doi: 10.1136/jnis.2011.004721.
12 Henkes H, Kirsch M, Mariushi W, et al. Coil treatment of a fusiform upper basilar trunk aneurysm with a combination of “kissing” neuroform stents, TriSpan-, 3D- and fibered coils, and permanent implantation of the microguidewires. Neuroradiology. 2004; 46 (6): 464-468. doi: 10.1007/s00234-004-1192-4.

Jean Raymond, MD
CHUM – Notre-Dame Hospital
Interventional Neuroradiology (NRI)
1560 Sherbrooke east, Pavilion Simard, room Z12909
H2L 4M1 Montreal, Quebec
Canada
Tel.: 514.890.8000 ext 27235
Fax: 514.412.7621
E-mail: jean.raymond@umontreal.ca